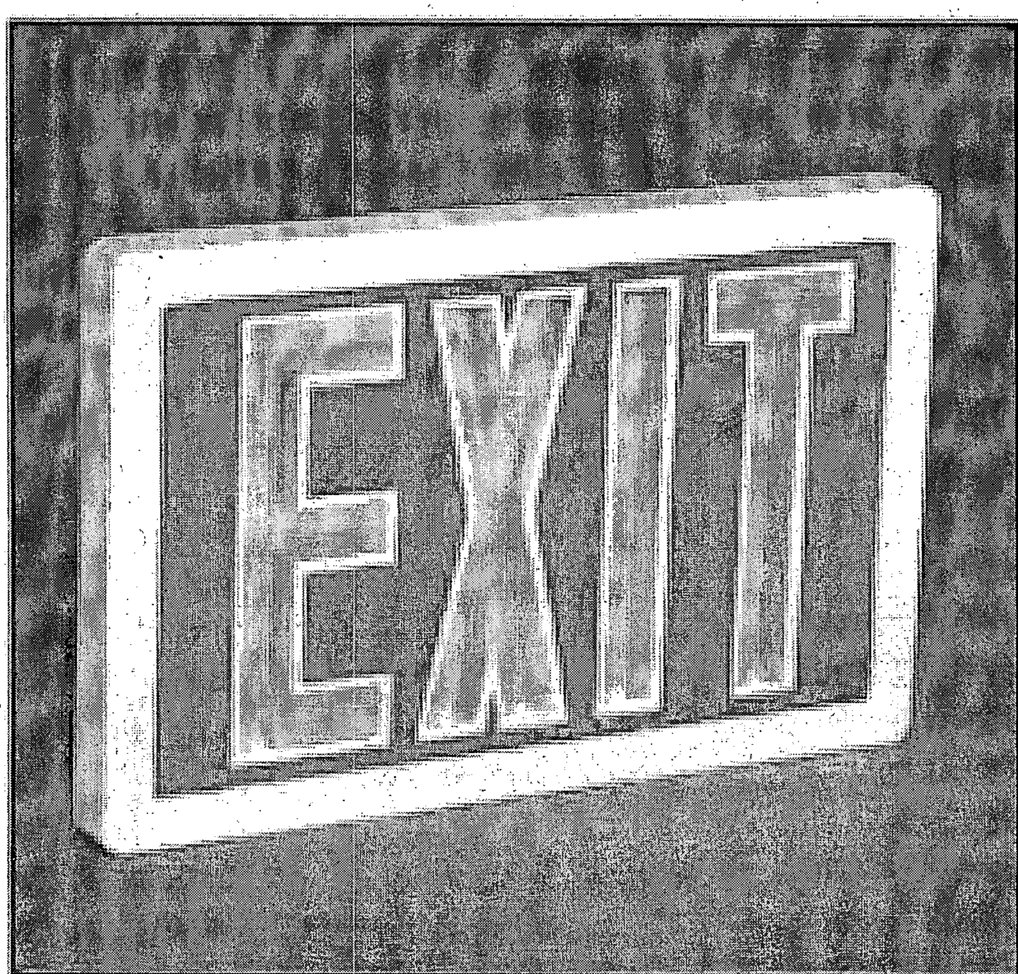
A Legacy of Light

U.S. Radium, the Safety Light Corporation, and the Luminous Industry in Pennsylvania



Report Prepared by the U.S. Army Corps of Engineers, Baltimore District

October 2012

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Introduction

The purpose of this report is to document the history and achievements of the U.S. Radium Corporation, later known as the Safety Light Corporation, in relation to the luminous industry in Pennsylvania. Luminous lighting is the use of radioactive materials to provide lighting that is self-perpetuating and operates without the use of electrical power. Luminous lighting has played an important role many different applications.

The report is prepared as mitigation for the removal of a historically significant complex of buildings in Columbia County, Pennsylvania, known collectively as the "Safety Light Property." This property has been contaminated by radioactive wastes, and listed as a National Priorities List (NPL) site for environmental cleanup by the Environmental Protection Agency (EPA) and the Pennsylvania Department of Environmental Protection (PaDEP). To fulfill the terms of a Memorandum of Agreement, the EPA contracted the Baltimore District, U.S. Army Corps of Engineers to provide a historic report on the property.

Development of Commercial Application of Radioactive Materials

Radium was discovered in 1898 by Pierre and Maria Sklodowska Curie. Madam Curie was a Polish scientist researching magnetism in metallic ores. She recognized two previously unknown element in the rock pitchblende, both of which were highly radioactive. When the Curies were finally able to separate the elements from the rest of the ore, they were able to distinguish two different elements not represented on the periodic table of elements, and named them polonium and radium.[i]

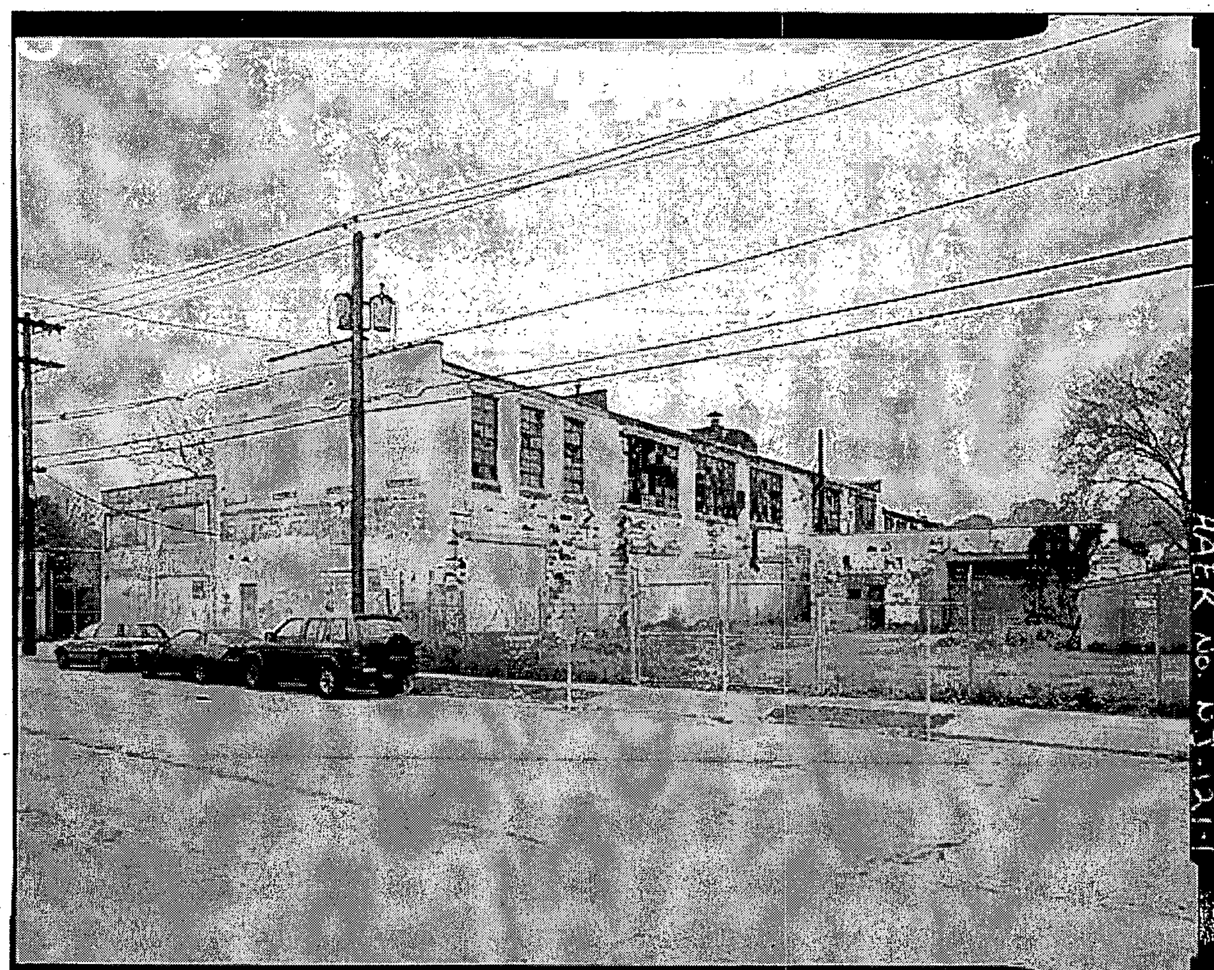
Soon after releasing the discovery, to the scientific community in a series of papers and a lecture at a physics conference in Paris in 1900, a wide variety of medical and commercial applications were developed to use the new element radium. Tests by the Curies had documented that radium will kill cells, and in 1903 Alexander Graham Bell is created with recommended that radium may be an effective cure to killing cancer cells[ii]. By the next year, medical applications of radium to treat cancer were developed. This "miracle cure" became the subject of wild claims in pulp magazines and hopeful magazine articles, and also in patent medicines and other "miracle" applications. At about the same time,

It was Madam Curie who first noted the luminous characteristic of radium. In 1904 she wrote: "The compounds of radium are spontaneously luminous. The chloride and bromide, freshly prepared and free from water, emit a light which resembles that of a glow-worm. This light diminishes rapidly in moist air; if the salt is in a sealed tube, it diminishes slowly by reason of the transformation of the white salt, which becomes colored, but the light never completely disappears. By redissolving the salt and drying it anew, its original luminosity is restored."[iii]

U.S. Radium Corporate Overview

U.S. Radium Corporation (USRC) was a leader in the manufacture of radium and radium isotope-based items for military and domestic uses. It played an important role in the development of many industries, and was significant for the role it played in the history of luminous lighting, in the development of medical test equipment, and in the production of color televisions.

One of the inventions in this period of fascination with the properties of radium was the development of luminous paint. The invention of radium-based luminous paint occurred in 1902 by William J. Hammer by mixing zinc sulfide with radium, to fluoresce.[iv] In 1914 the United States Radium Corporation was founded by Dr. Sabin Arnold von Sochocky and Dr. George S. Wills as the Radium Luminous Material Corporation, originally intendnig to mass produce radium for medical applications. They initially produced radium from carnotite ore transported from Utah and Colorado, but eventually began producing radioluminescent paint. They established a manufacturing plant at Third Street, Newark, New Jersey, in January 1916. In 1917, the Radioluminous Materials Corporation established an ore processing facility at Alden Street, West Orange, New Jersey. During their years at the facility, they refined the ore to remove the radium from it, and discarded all the radioactive ores in the back of their property.



Original USRC Paint Plant, Orange, NJ,(HAER NJ-121,7-ORA,3-

In September 1921, the company was reincorporated as the United States Radium Corporation (USRC), headed by Chairman Arthur Roeder. [v] In 1926, they closed the West Orange facility and relocated their manufacturing base to Brooklyn, New York. Radium processing at the Orange facility ceased in 1926, and USRC vacated the premises. Despite USRC's departure from Orange, the company retained ownership of that site and continued to produce fluorescent compounds, in Brooklyn, New York. In the mid-1930s USRC leased the Orange factory to various commercial tenants, eventually selling the property in 1943 to Arpin, a plastics manufacturer. Despite its suspicions about the harmful effects of radium, as recited above, USRC did not remove the discarded tailings from the site.[vi]

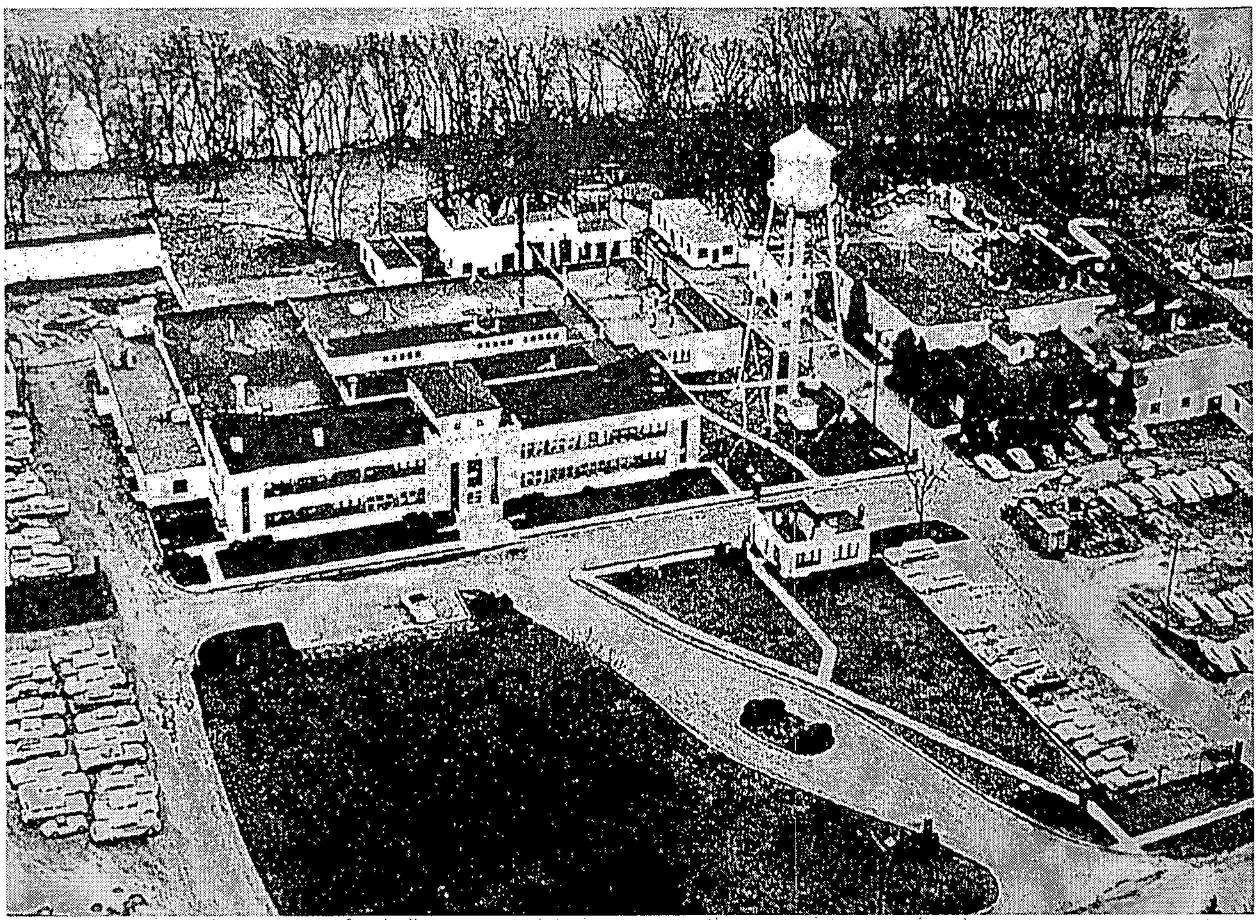
From 1926 to 1948, they continued their manufacturing in Pearl Street, Brooklyn and elsewhere, with the painting of radium dials at their Brooklyn facility. In 1942, because of the large quantity of defense contracts they had received, U.S. Radium expanded to its greatest size, employing 1000 workers.[vii] Although they continued painting watch dials and other instrumentation, they had been forced by the Consumer's Bureau of New Jersey to implement better safe handling practices of the radioactive materials, and in 1947, developed a screen printing of the watch and other dials, ending the hand painting of the dials.[viii]

After the war was over, U.S. Radium decided to relocate their production to Bloomsburg, Pennsylvania. The Bloomsburg area was suffering economic distress caused by the end of old industries in the area, and they were courting various industries to move into the area. U.S. Radium felt that this would be a good source of labor. They also wanted to distance themselves from the notoriety of the Radium Girls lawsuit and its effects in the Greater New York metropolitan area.

Their facility at 4150 Old Berwick Road, Bloomsburg, was opened in 1948. The complex consisted of ten buildings, including the main building, which is the oldest structure at the complex. It is a brick building with wooden framing and metal roof. By the time they relocated their operations to Bloomsburg, they has established the screen printing of the dials, and incorporated the use of vacuum hoods, protective clothing, decontamination, and other safety practices to protect the workers from any contamination. Because of this, the former Almedia Toy Factory facility was gutted and remodeled after it was purchased to incorporate these new processes.

At the Bloomsburg facility, they continued to produce watch dials, but increasingly expanded their product lines to incorporate anything they could manufacture that required the use of radioactive materials. During World War II, they had become renowned for manufacturing a variety of implements for the Department of Defense. They had a large business in luminous signage, dials for all forms of instruments, markers for ships and bridge abutments, and the earliest forms of smoke detectors.

In 1968, U. S. Radium was reincorporated as the Nuclear Radiation Development Company, with its corporate offices in Grand Island, New York, and its facility in Bloomsburg operating under incorporation as the Safety Light Corporation. They continued to produce illuminated signs with modern, non-radioactive materials, producing glow-in-the dark signs, dials and other luminous paint products. They pioneered the use of tritium in the manufacture process of luminous signage by encapsulating the gas in closed glass vials.[ix]



Aerial View of Bloomsburg Facility, 1950s

The company began a precipitous decline through the 1970s. A number of factors contributed. The American economy was poor, with high unemployment, high interest rates, and poor sales. Television sales were down dramatically, and with it, the company's sales of phosphors to that industry. In 1976, they were forced to sell their medical apparatus portion to GAF Corporation, due to competition from Eastman Kodak, which had entered the X-ray film business in the early 1970s. This sale caused the company to suffer a substantial loss in profits for the remainder of the decade.[x]

In the 1960's, the workers at U.S. Radium had become unionized, and in the 1970s went on a lengthy strike. The end result of the strike was that the company lost most of its most lucrative clients, and the company was drastically downsized afterward. Following a peak employment of 500 people in the 1950's, the Safety Light Company emerged from the strike employing less than fifty people, and that size continued to shrink as their product line diminished.

In 1980, due to internal disputes, the metal production and dial screening portion of U.S. Radium was divided off of the company and formed its own corporation, under the name of USR Industries, Inc. It continued to occupy the southern half of the main Bloomsburg building, as a separate entity, and provided the dials and metal sign casings to U.S. Radium by the piece.[xi]

The company was also facing increasing scrutiny from the Environmental Protection Agency and Pennsylvania Department of Environmental Protection for repeated violations of environmental laws. By 1979, U.S. Radium began to face lawsuits to clean up their former property in West Orange, New Jersey, and ultimately all of their former sites, and also faced mounting costs for expanded monitoring water and air emissions and control of radiation waste at their facilities.[xii]

The Atomic Energy Commission stopped producing tritium after a ban went into effect in 1988. Eventually, the U.S. government banned the manufacture of items using tritium gas in the country, and Safety Light was forced to relocate its manufacturing facility to Canada. At the present, discarded tritium exit signs are cited as the main source for tritium contamination of Pennsylvania landfills. The Safety Light Corporation, formerly U.S. Radium, ceased operations at the Bloomsburg plant in 2007. The plant at Bloomsburg was found to be highly contaminated, and listed on the National Priorities List of the Superfund program. It is currently a part of a lengthy EPA remediation, and the complex is scheduled for demolition and abatement.

Ore Processing

Although uranium mines were common in Europe, it was not until 1871 that the first United States sources for radioactive materials in native ores was found. In that year, a British metallurgist discovered carnotite in Colorado, which is an ore containing a small amount of uranium.

There were, however, very low yields of radium in the American ores. It was necessary to process five hundred tons of ore to extract one gram of radium salts.[xiii] Because of the low yield of the American ores, most early radium work utilized European supplies. However, the rising cost of processed European radium eventually made using the low-yield American ores lucrative. The first company that commercially manufactured radium was the Standard Chemical Company, beginning in 1913. By 1918, there were six companies producing 13.5 grams of radium a year.[xiv] Because of the high cost of the European suppliers, U.S. Radium established their own mining operation in Paradox Valley, Colorado and began their own processing operation at a plant they built in West Orange, New Jersey.

The carnotite ore used by the company was primarily Uranium 238 and vanadium. Raw ores were shipped to New Jersey from mines in Utah and Colorado. At the New Jersey facility, the ore was crushed into a powder and the uranium extracted. The manufacturing process was only able to recover approximately 80% of the radium from the nature ore, and the company simply discarded the remaining 20% of waste or tailings into unused areas of their Alden Street property, with no form of containment.[xv]

However, the discovery of high grade ores in Belgium eventually destroyed the American mining industry. While American ores yielded one gram of radium for each 400 tons of raw material, the Belgian ores produced the same amount with only 10 tons of ores. Mining operations in America were soon put out of business, the one owned by U.S. Radium ceasing its operations in 1926. The industry relied on the Belgian ores until after World War II, when the emerging nuclear industry was able to produce manufactured radiological materials like tritium, as byproducts of the nuclear reactions. These products were sold to industrial manufacturers by the Atomic Energy Commission.

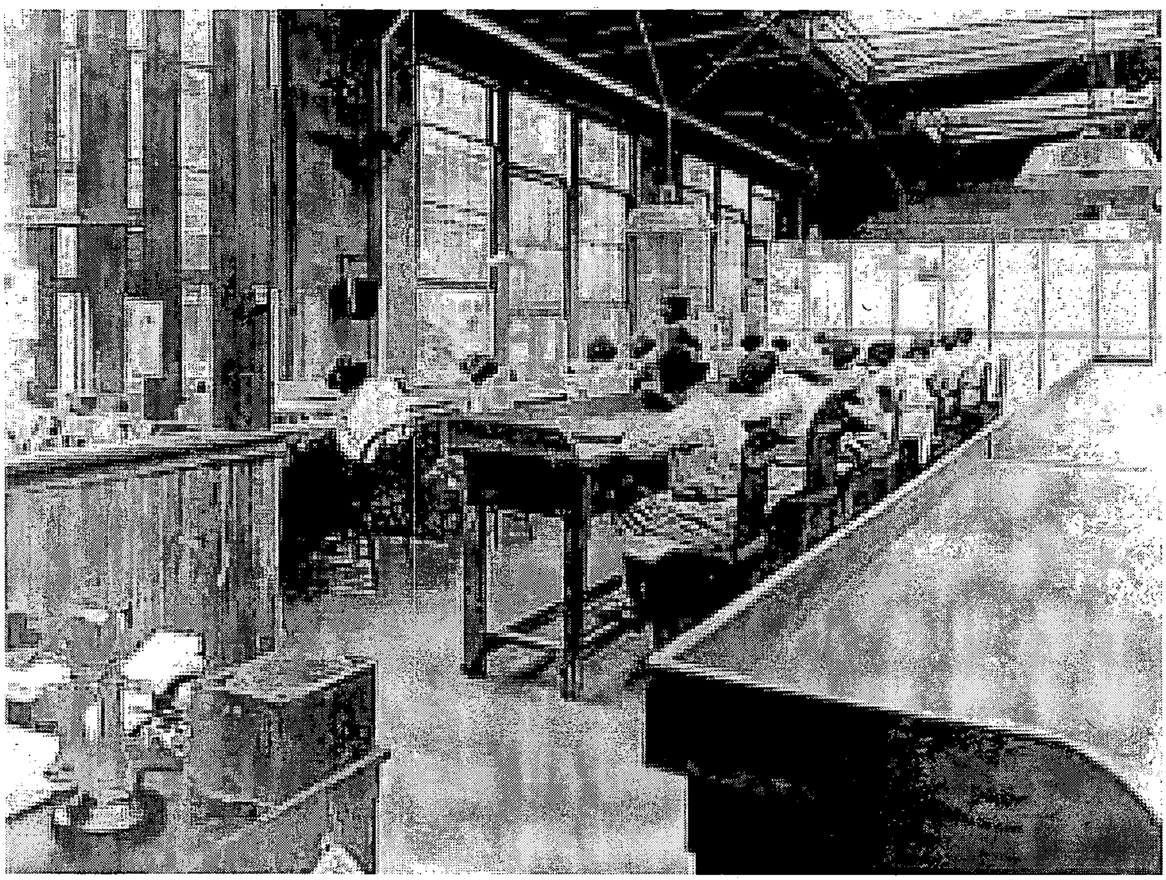
Luminescent Paint Industry

After the ore was processed, the radium was mixed with other chemicals to produce a paint. Patented under the trademark "Undark", this paint was used primarily for use of the dials of watches and airplane instruments. The use of radium on watches and instruments began during World War I, under contract to he Army, so soldiers could use their watches and compasses in the dark without turning on a light, and by producing illuminated dials for aircraft so they could fly at night. The military application of the luminous paint industry was vital in the military operations of World War I.

After the war was over, luminous dials on watches began to be advertised as a fancy item for business executives, even though the amount of radium used in the paint was much lower than the military applications, and by the early 1920's had become sufficiently popularized that it was being advertised for watches for the general public.[xvi]

The U. S. Radium Corporation actively advertised their product, including hosting a nationwide tour to universities and trade shows of carnotite ore, Undark, and some of the products that could be made from it. After 1917, the company used mesothorium, an isotope of radium (Ra-228), which was more readily available than radium (Ra-226), which was used almost exclusively in the medical industry.[xvii] According to an article about the paint in 1922, "it was being promoted for "automobile gasoline gauges, aeroplane implements, poison bottles, house numbers, light indicators and other mechanical and household objects". [xviii] USRC marketed Undark in its liquid form directly to various department of the War Department, who routinely used it to mark dials, hatches, clocks, name plates, aiming devices on Army, Navy and Air Force property.[xix]

Commercially, USRC obtained contracts from many watch companies to produce the dials for their watches. The paint was applied manually, generally by female workers at the facility. At the time that this practice was common, although the health risks of radium were suspected by scientists in the industry. The executives and ore handlers wore protective clothing around the materials, but the common day laborers were not informed or encouraged to use any safe work practices[xx]



Radium Dial Painters (From Glassmire 2010)

Dial Painters (Stannard, J. N. *Radioactivity and Health: A History.*)

Corporate logo of the Undark Paint Brand (Glassmire 2010)

Approximately 4,000 workers nationwide are thought to have been involved in the radium dial-painting industry between 1912 and 1940. At the USRC plant in Orange, NJ, there were 70 painters. They used a mixture of glue, water and radium powder, applied with camel hair brushes. The going rate at the time was for painting 250 dials, at one and a half cents per dial. The brushes would lose their shape, and the workers were told to point the brushes with their lips or tongue. One worker remembered that she would "point" the brush six times for each dial. Unaware of the risks, the workers were known to paint their toes, teeth and eyelids with the radioactive powder for Saturday night dates.[xxi]

Severe health affects began to appear in the workers at the Orange facility, which consisted of "a painful swelling and porosity of the upper and lower jaws, and ultimately the death of many of these women."[xxii] The medical illness became known as "Radium Jaw" or "Radium Necrosis", and was directly linked to the unhealthy manufacturing process at this plant. Initially, the company denied any culpability with the illnesses. They contented that the x-rays from their doctors were making them sick, or they were attributed to sexually transmitted diseases. By June of 1925, five deaths had occurred under similar circumstances at the plant, including the death of Dr. Edward D. Leman, chief chemist at the facility.[xxiii]

Fearing liability, USRC hired Harvard professor Cecil Brinker to do an environmental study of the facility. He found radioactive materials covering the entire facility, and observed numerous health problems with the workers. However, his report was ultimately covered up by the president of USRC, Arthur Roeder. Roeder even released a statement that Brinker's report has said that:"every girl is in perfect condition." When the actual report was ultimately released, the opposite was found, for Briner reported "...Dust samples collected in the workroom from various locations and from chairs not used by the workers were all luminous in the dark room. Their hair, faces, hands, arms, necks, the dresses, the underclothes...even the corsets of the dial painters were luminous. One of the girls showed luminous spots on her legs and thighs. The back of another was luminous almost to the waist..."[xxiv]

A former worker, Grace Fryer, had been a dial painter at USRC from 1917 to 1920, but then received a new job at a bank. Several years later, she began to suffer severe health problems. Her teeth began to fall out, and she suffered from serious abscesses and jaw pain. When she was x-rayed, it was found they she has severe deterioration of her jaw. Facing increasing sickness and medical costs. In 1925, Fryer decided to sue the company, but it took her two years to find a lawyer who would be willing to take on the company. Four other factory workers, Mrs. Quinta McDonald and Mrs. Albina Larice of Orange; Mrs. Edna Hussman of Hillside, and Miss Katherine Schaub of Newark joined her in the suit.[xxv]

The outraged press dubbed them the "Radium Girls." The outcome of the lawsuit in the summer of 1928 resulted in an award of $10,000 to each plaintiff ($127,589.47 in 2010 dollars); lifetime payments of $600 per year; and all of the medical and legal costs covered by the company.[xxvi] Other lawsuits and deaths occurred for decades after this settlement. Miss Fryer, the center of the lawsuit, died from the cancer in 1933.[xxvii] Ultimately, 43 deaths were attributed to the workers practices at the Orange plant.[xxviii]

The "Radium Girls" 1)- Upper row: McDonald, Larice and Hussman. Bottow row: Schaub and Fryer (St. Petersburg Time, 1928)

After losing the lawsuit, USRC posted warnings cautioning its employees against sharpening the brushes in that fashion.[xxix] The court case resulted in improvements to workers in unhealthy conditions and increased scrutiny of the government in hazardous industries (Radium Girls, n.d.).

A similar company in the 1920s was the Radium Dial Company of Chicago. They received a contract from the Westclox Clock Company, and as a result, relocated their operation to Peru, Illinois. At the Radium Dial Company, several women also contracted "radium jaw" and died, but they continued to use radioactive paints until 1940, when they relocated the company to New York City.[xxx]

Other health effects were later recognized regarding radon gas, a byproduct of naturally occurring radium. The toxic affects of the radon gas were not recognized until the mid 1930s, and it was not until the 1960s that a definitive association between radon gas and radioactive mine tailings was accepted. Even so, it was not until 1978 that radioactive mining tailings began to be regulated by the Environmental Protection Agency.[xxxi]

It was not until the mid-1950s, however, that the scientific community engaged in any serious study of the epidemiological risks associated with radon. It did not generally accept the link between radon and lung cancer until the 1960s, and it was not aware of the problems generated by radioactive tailings until the late 1960s. The federal government, reflecting an unfortunate lag time, did not regulate the disposition of tailings until 1978.[xxxii]

Bloomsburg Facility

The U. S. Radium Corporation relocated from their facilities in Brooklyn, New York and West Orange, New Jersey to Bloomsburg, Pennsylvania in 1948. They purchased the former Almedia Toy Factory, in Centre Township, Columbia County. Their move was partly designed to give the company a fresh start, away from its negative history in the greater New York area, and partly to tap into a pool of cheaper labor. They have produced great profits during World War II, and only with a new, dedicated site, could they expand their production lines into new commercial applications. U.S. Radium began construction of the new plant in the spring of 1948, with completion expected by the fall of the same year. The annual Board of Director's meeting was held at the site in May 1948, where the board members could see the construction of the facilities at the Bloomsburg facility. Although US Radium was able to reuse the toy factory building, other structures were built in 1948 to serve as various dedicated work areas for the new operations.[xxxiii]

Aerial View, 1950s

A Newcomer . . .

Although we're one of the newest industries in this area, we're mighty happy of being here.

The United States Radium Corporation is providing employment for scores of men and women; helping to make possible a better and more prosperous America today and tomorrow.

manufacturers of

WATCH, CLOCK, and INSTRUMENT DIALS

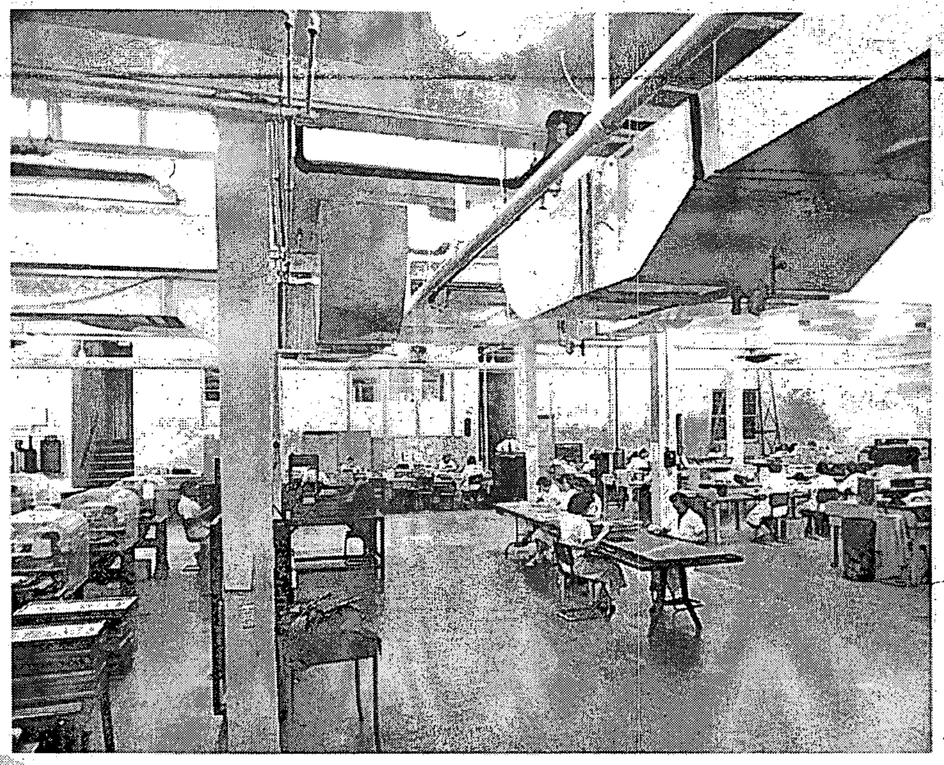
and

RADIO ACTIVE PRODUCTS

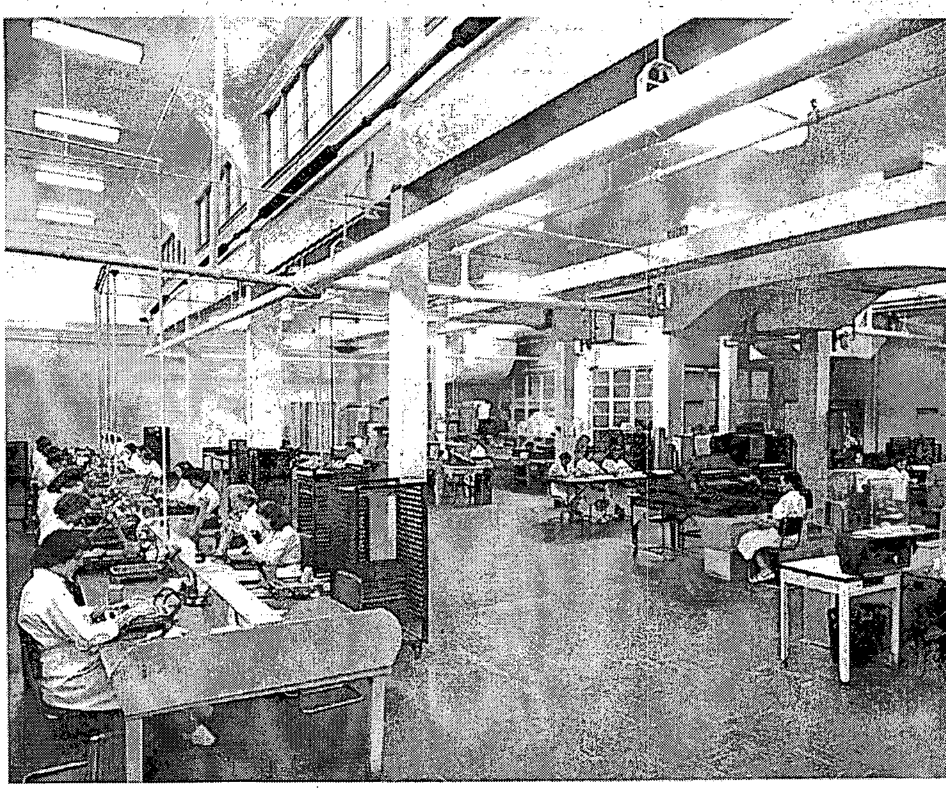
UNITED STATES RADIUM CORP

ALMEDIA, PA.

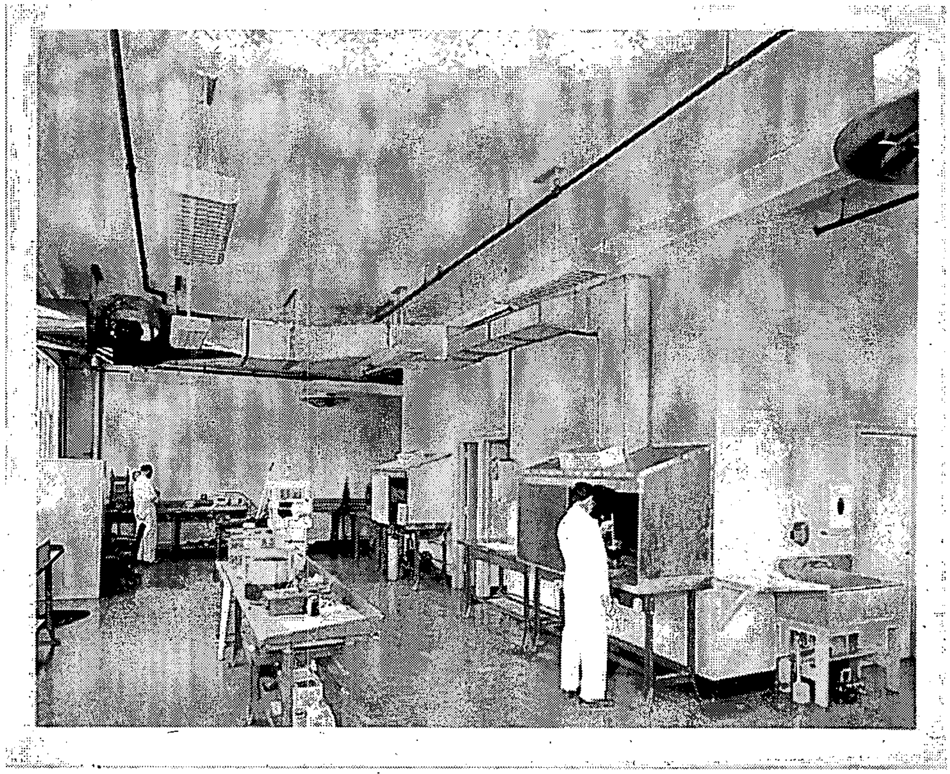
Early Advertisement for Bloomsburg Facility



Production Floor, 1950s



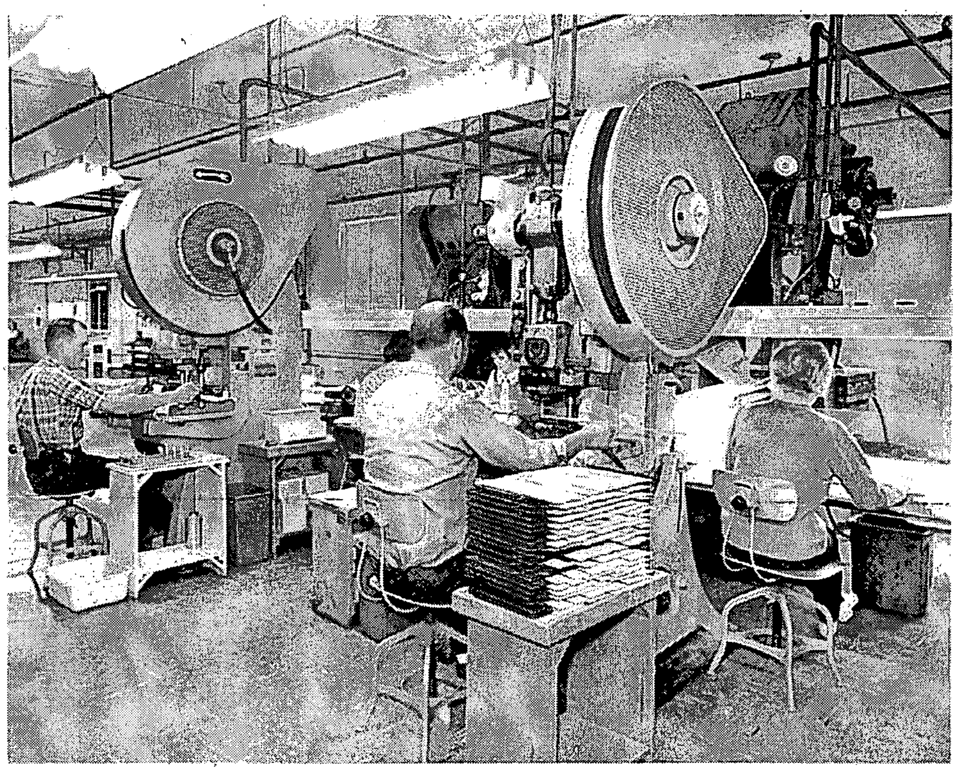
Dial Screen Printing, 1950s



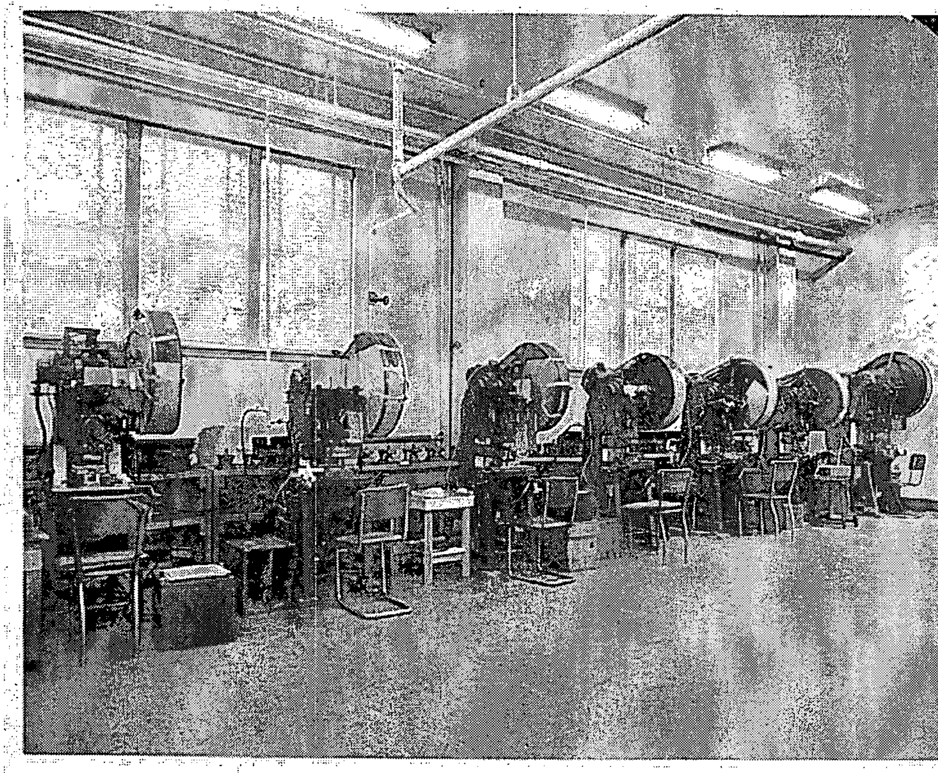
U.S. Radium Laboratory, 1950s

Production Area

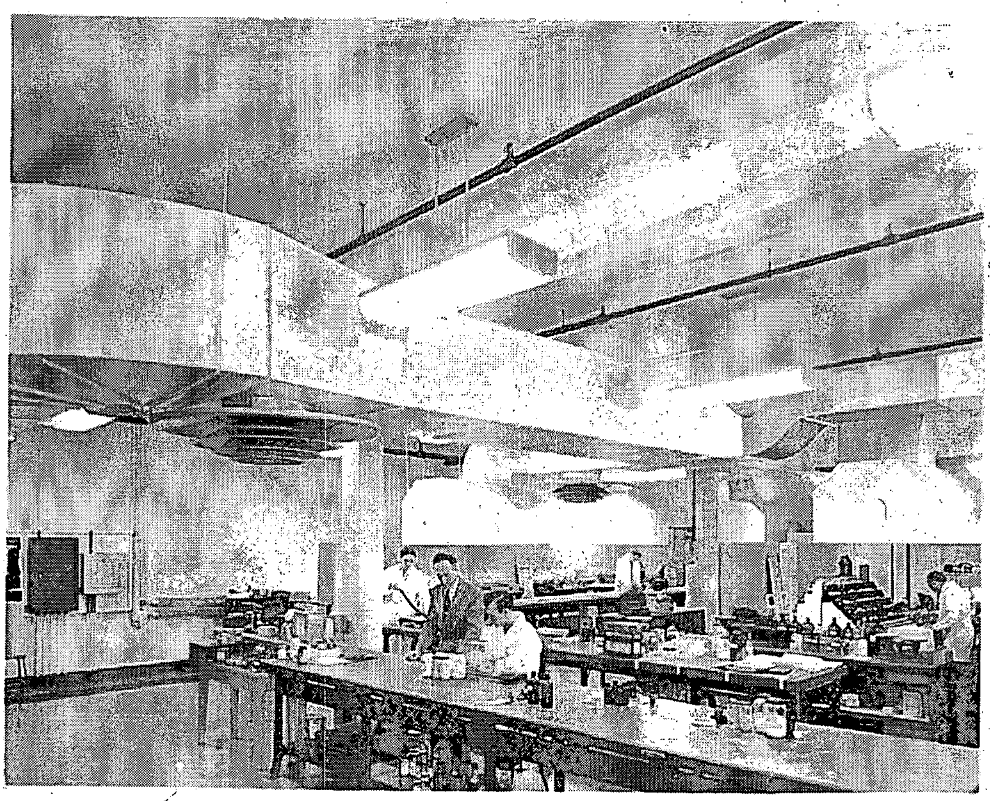
U.S. Radium, Watch Dial Painting



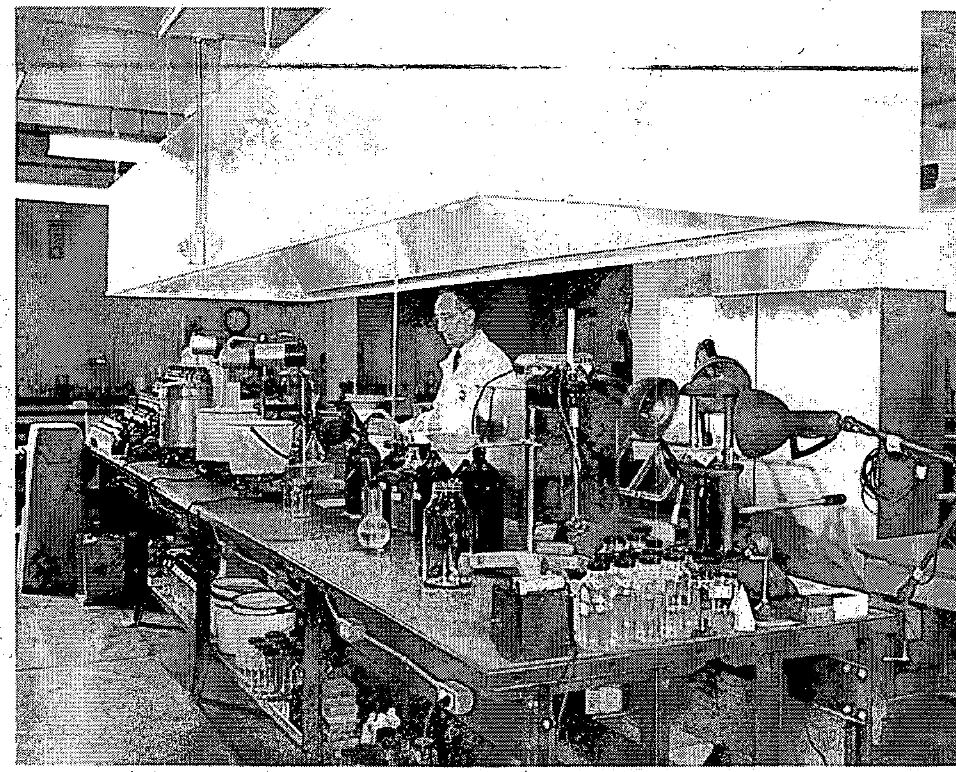
Punch Press Operation



Punch Presses, U.S. Radium



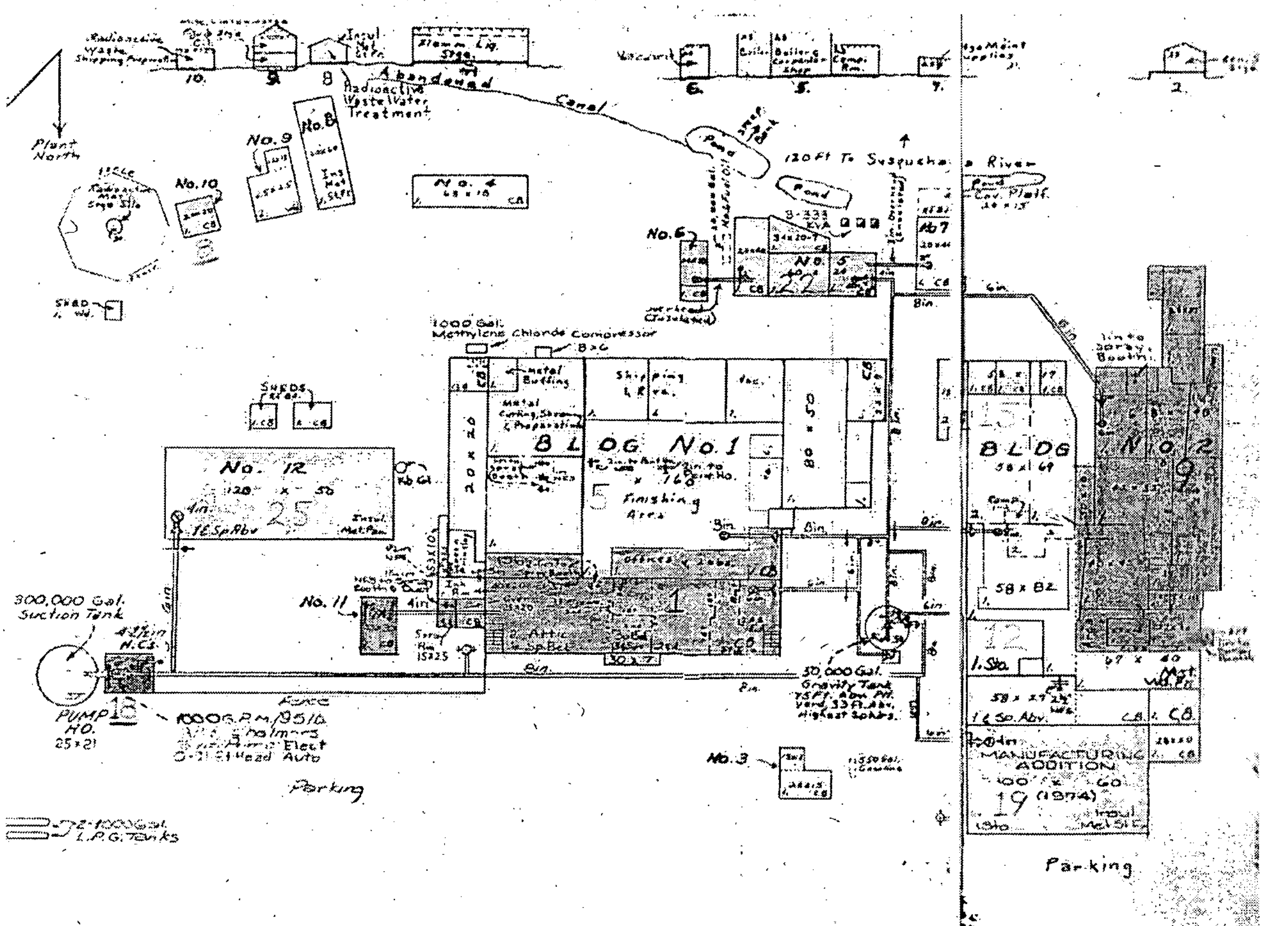
U.S. Radium Research and Development Laboratory



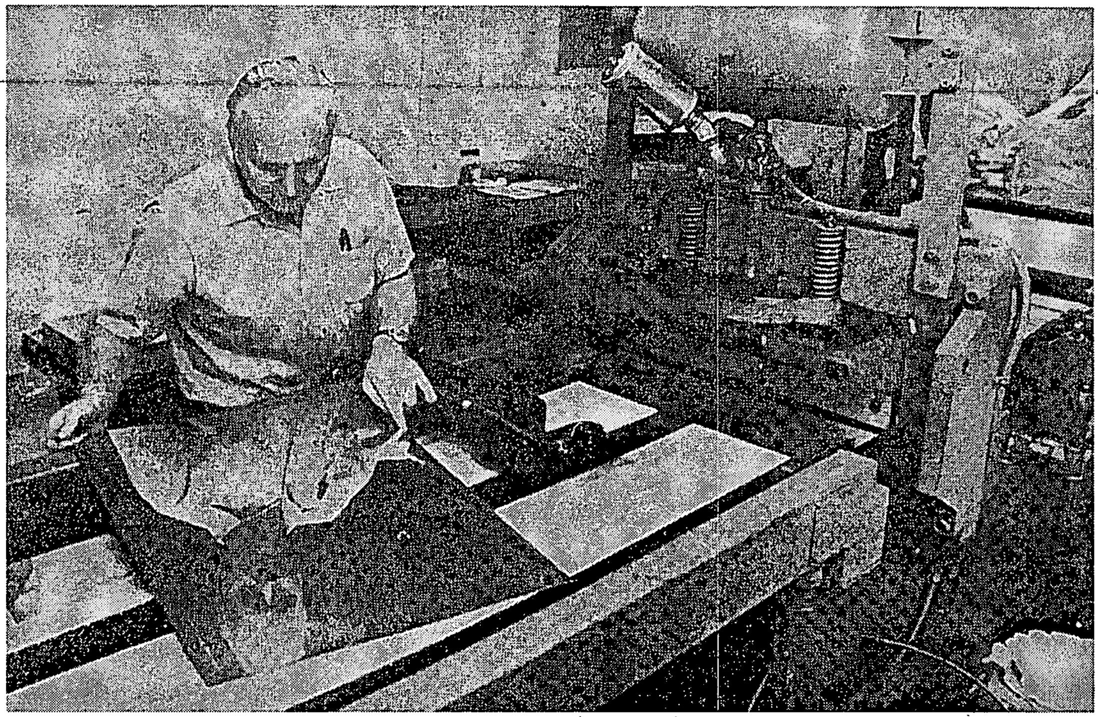
U.S. Radium Laboratory

The new facilities were described in depth by the Army, following a visit to the plant in May of 1951: "The main laboratory is housed in a modern building only three years old; it is of brick and glass block construction, and clean and orderly inside. The laboratory in which the SR-90 is to be used is 25' by 30' and air-cooled. It has two six-foot hoods mounted back-to-back in the center of the room. The hoods are made of stainless steel with one-half inch Lucite sliding doors. The air flow is of the order of 100 feet per minute. Two large gloved boxes, each equipped with a filter and a vacuum blower, are available, together with a large quantity of remote-controlled tongs, both mechanical and vacuum type. Two G-M survey meters, a Cutie Pie, and a Nuclear Research Corporation count rate meter were at hand. There was no evidence that this laboratory had been cleaned up especially for the visit by the Isotopes Division representative. Laboratory personnel wore clean laboratory coats and film badges and pen meters. The floor was of plastic tile and was well-waxed and clean."[xxxiv]

The processing areas for both the painting and the final assembly of instrument dials was described as well: "I was shown the room in which numbers are painted on clock and instrument dials with radioactive paint. A large room, approximately 40' by 60', is used for this purpose. Approximately 50 girls were employed at the time, each one having in front of her about 1 gram of paint containing 5 mg of radium. Individual tables are provided for each worker and a small plastic hood, approximately 12" by 18" and 6" high, is at the head of each table. Each hood is connected to a duct for removing any radon emanation. A lighted match, held near one of the hoods, indicated ample air flow. Every fifth girl wears either a film badge or a pocket ionization chamber. The floor of the room was asphalt tile, well-waxed and spotless. Each of the girls wore clean uniforms and a white cap, the clothing furnished by the U.S. Radium Corporation., None of the girls were gloves, and upon questing, the writer was shown the fluoroscopic examination room through which each person passes before leaving the assembly floor, and the writer was shown how easy it is to detect extremely small quantities of radioactive materials in the form of radium paint. Fingernails are kept very short, and a standardized scrubbing and decontamination technique is used if any radioactivity is detected...The writer was shown the assembly floor where it is proposed to fit the sources into the metascope. This room is approximately 40' by 50' wide, is air-cooled, has a linoleum floor, and is neat and clean. The equipment which has been used to assemble radioactive dials in various aircraft instruments was demonstrated. The dials are handled under a small plastic hood approximately 12" by 18", the air flow being away from the operator. A complex mechanical assembly fastened the radioactive dials to the instrument and there was little, if any, opportunity for human contact."[xxxv]



Schematic of Bloomsburg Facility, U.S. Radium


Operator off Automatic Metal Cutting Device, US Radium

In the 1950's, one worker from the US Radium plant at Bloomsburg said "She would take the potent powders out of the box and mix them with other ingredients in a small glass bowl to make glow—in-the-dark paint. She would then paint clocks and other items."[xxxvi]

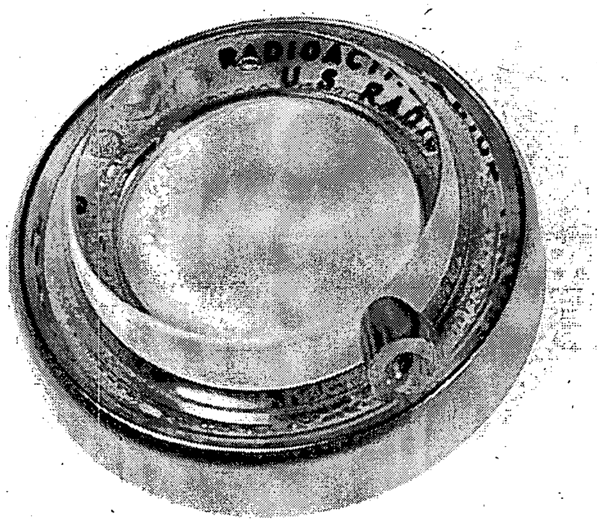
Production Items

At the new facility, the company was able to greatly diversify its product line. Anything that required a radioactive source or was activated by a radioactive gas could be finished at this location. In general, the items were manufactured elsewhere, but U.S. Radium provided the vital final step by adding the radioactive material and then sealing it so no radiation would escape. Years of experience with sealing radioactive materials inside watch cases had led to the concept of sealing different radioactive materials in a wide variety of different items. In its early history, SLC used radium 226 (Ra 226) and polonium 210 for light sources or other manufacturing processes beginning in 1948. The USEPA states in their Hazard Ranking Documentation that manufacturing at the facility used hydrogen 3 (tritium, H 3), carbon 14, cobalt 60, nickel 63, krypton 85, cesium 137 (Cs 137), promethium 144, thallium 202, and Ra 226 which was the most widely used radionuclide (1). In the 1960s, unspecified processes replaced the use of Ra 226 with americium 241 (Am 241) (2). Later, strontium 90 (Sr 90) and Cs 137 were used for civil defense devices and deck markers for the US Navy, respectively. By 1979 they were only using tritium (H3) in their manufacturing process. The H 3 was used for emergency lighting devices. SLC held two licenses for use of radioactive material issued by the US Nuclear Regulatory Commission (USNRC) or its predecessor, the Atomic Energy Commission. The licenses, License Number 37-00030-02 (for the cleanup) and License Number 37-00030-08 (tritium use) expired on December 31, 2007 (3). (ATSAD 2009)

Deck Markers

During World War II, U.S. Radium became very involved in the manufacture of deck markers for U.S. Naval vessels. These followed the same general procedures are other items, the placement of Strotium-90 on a metal strip. And then sealing the strip inside a plastic case that could then be safely handled and inserted in the proper locations of the ship's decking. A later letter reported that the Navy had purchased 300,000 deck markers from the company.[xxxvii]

Later, U.S .Radium was using Krypton-85 as the catalyst for the markers. In 1957, they has standing orders for tens of thousands of the markers. It was described that they were manufactured with a small rubber seal in the back. The U.S. Radium worker would puncture the seal with a hypodermic needle attached to a Krypton gas source. When the needle was removed, the rubber seal would close, and then the seal itself would be permanently covered to prevent gas leakage.[xxxviii]

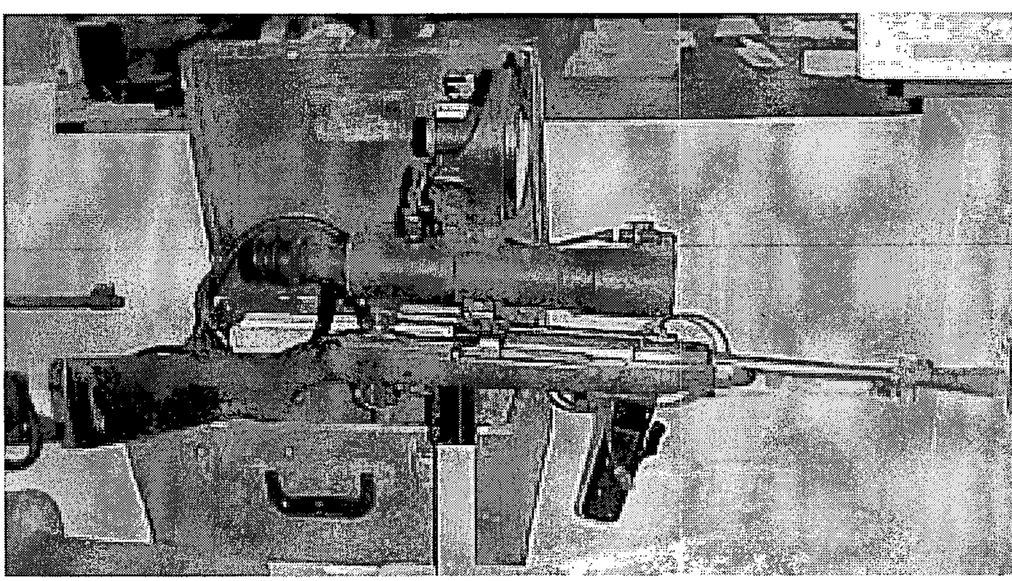


Deck Marker by U.S. Radium, 1950s

US Radium Deck Marker Box, sized for eight Deck Markers

Night Vision Scopes

One of the first major new products made at the facility were "metascopes", or night-vision scopes. First developed during World War II, the improved Sniperscope used a battery, infrared filters and a small amount of Strotium-90. U.S. Radium received a contract from the U.S. Army in 1951 to add the SR-90 to the sniperscopes under a top secret classified operation, with a production of 20,000 units. The sniperscopes could be added to any M1 or M2 carbine rifle. .



M3 Carbine with Strontium Activated Night Scope

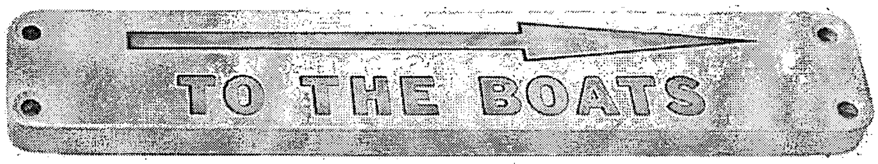
U.S. Radium's role was to apply the SR-90 to half-inch metal discs, and seal them into the scopes. The Strotium-90 was supplied by the U.S. Atomic Energy Commission at a rate of 500 millicuries per week. In a then-highly classified letter in 1951, the entire manufacturing process was described, which anticipated producing 1000 units per week.[xxxix]

Tritium Gas Signs

A memo from the AEC, dated April 29, 1953, states the U.S. Radium had contacted that office regarding experiments of the use of tritium in the manufacturing of luminescent sources.[xl] Tritium gas reacts with phosphorus to emit light, and is less radioactive than radium. They were able to experiment with the isotope, and found that the use of tritium gas was the safest and easiest way to handle it, and suggested applying a phosphor to the inside of a glass tube, then filling the tube with tritium gas and sealing the open end of the tube.[xli] It was with this method that Safety Light was able to manufacture luminous signs without the continued use of radium.
A new tritium facility was constructed at their Bloomsburg plant in 1968-1969. Because of the dangers of radioactivity in illuminated materials, research was extensively conducted to find a replacement material that would be safer to handle. Tritium illumination uses a gaseous tritium, a radioactive isotope of hydrogen, to fluoresce. As the gas undergoes decay of its "beta" elements, it emits light without any electricity. It is therefore a useful gas for lighting emergency exist signs, and also a safe alternative for watches, auto and airplane instrument dials, compasses and weapon sights.

Tritium Filled Exit Sign, U.S. Radium

Diversification continued through the 1950s. In a memorandum written by the AEC in 1957, it is stated that U. S. Radium had asked to dramatically increase their supply of Tritium and and Krypton-85 At a visit to the facility, the AEC reports, "We were first shown quite a number of different type light sources which they are planning to offer for sale if they obtain the necessary supply of Krypton 85 and tritium. They have orders for large numbers of sources for military applications, such as range setting scales for mortar shells, exit and hatch markers for Naval vessels or aircraft, and markers for use on military bridges and through mine fields."[xlii]



Naval Marker, U. S. Radium

In 1957, U. S. Radium received a request from the New York Central Railroad to manufacture 54 signal lights for the railroad using similar production techniques. These were to be a single piece of cast aluminum with four bulbs, containing Krypton-85 mounted in a reflector behind a rectangular screen and window lenses. The assembly would then be placed on top of a 9 foot pole and secured.[xliii]

The annual report for U.S. Radium, in 1959, reported that the company was producing no less than 17 product lines[xliv], as shown in Table 1.

Table 1: 1959 Product Line, U.S. Radium

Electroluminescence	Development of an expanded line of electroluminescent phosphors and devices to meet the growing scope of industrial and military application.
Ion Separation Devices	Development of techniques and equipment for separation off positive and negative ions, and conduction of those with desired polarity to required locations for possible applications in air conditioning systems, therapy and static elimination
Krypton-85 Static Elimination	Application studies leading to eventual marketing of a device to eliminate friction static in many industrial processes, such as paper handling, textiles, plastics, etc.
Infrared Sensitive Phosphors and Screens	Development of specialized phosphors for a variety of infrared applications

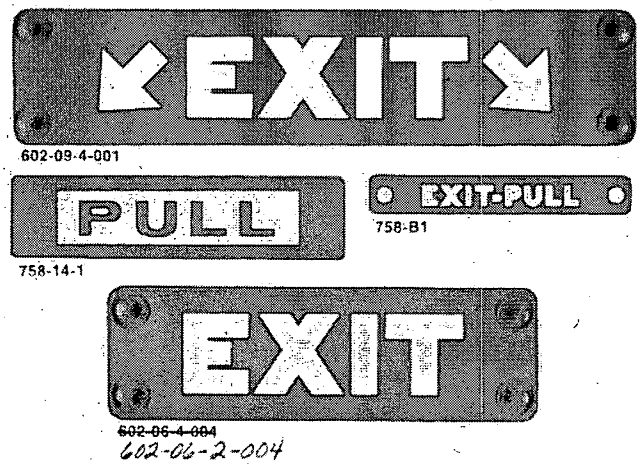
Tritiated Luminous Compounds	For use as a substitute for radium and other isotope activated luminous materials
Special Illumination Techniques	Adaptation of self-luminous isotope-activated materials to illumination of compasses, fire control equipment and other military devices
High Quality Watch Dials	Development of finishes and methods of faceting and diamond polishing by mass production techniques
Tritium Foils	Development of a method for producing uniform tritium foils for use as activators in phosphor light sources, gauging, targets for radiation bombing, etc.
Solid State Image Amplifier	Development of a device for producing extremely bright images in industrial and medical fluoroscopy
Photographic Dodging Equipment	Design of a low-cost device for improving quality of photographic negatives or prints through control of area and line contrast
Phosphors for Air Tracer Study	Development of trace phosphors for determining the composition and/or construction of air pollutants
Integral Instrument Lighting	Refinement of instrument lighting techniques to evolve a method for efficient internal illumination
Product Identification Phosphors	Development of phosphors which, when mixed with material, enable ready product identification
Thermographic phosphors	Development of heat-sensitive materials to be used for detecting flaws in metal laminations, lightweight casings and other applications
Alkali Halide X-Ray Screens	Development of a new high speed type intensifying screen for use in medical and industrial radiography
Color Television Phosphors	Development of more efficient phosphors for use in color television tubes
Radioactive Light Sources	Design of new sources for low-level brightness applications where long-life, low maintenance and elimination of power supplies are requirements

USR Bulletin 30.50

ISOLITE®

SELF-LUMINOUS AIRCRAFT EXIT DISPLAYS & MARKERS

TECHNICAL DATA



Design Features

■ Self-Powered ■ Always "On" ■ No Wiring ■ 10-Year Half-Life ■ Simple Installation ■ No Maintenance ■ Compact ■ Lightweight ■ Maximum Brightness

DESCRIPTION

Isolite self-luminous "exit" markers are illuminated by isotopic-powered tubes in which low energy particles produce light by exciting the phosphors used to coat the interior of the tubes. Tube light is uniformly diffused throughout the marker or sign. The tubes are totally sealed sources. There is no measurable radiation beyond the glass tube.

The structure itself is strong, light-weight and designed to accept heavy external shock while still affording maximum protection to the glow tubes (U.S. Pat. No. 3,402,492). The signs are mounted easily through the use of four corner-mounting grommets. No maintenance is required.

Several levels of brightness are available from stock. A minimum standard is [illegible] microlamberts, the high brightness is in excess of 400 microlamberts. AEC licensing is not required for aircraft holding FAA certification. Signs and markers are also available for ground trainers and flight simulators.

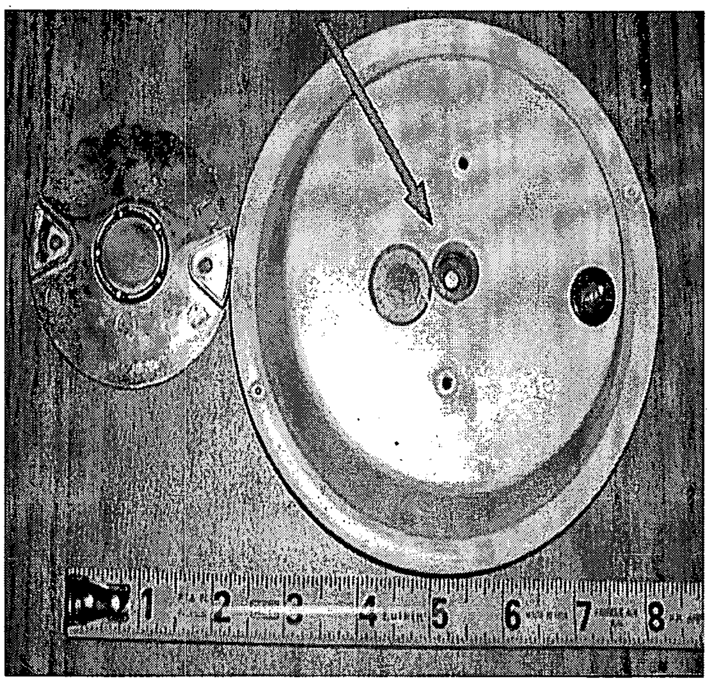
Approved AEC General License 29-13537-02G

SAFETY LIGHT CORPORATION
4150-A Old Berwick Road/Bloomsburg, Pennsylvania 17815
Telephone: (717) 784-4344

Brochure of Tritium Lighted Signage

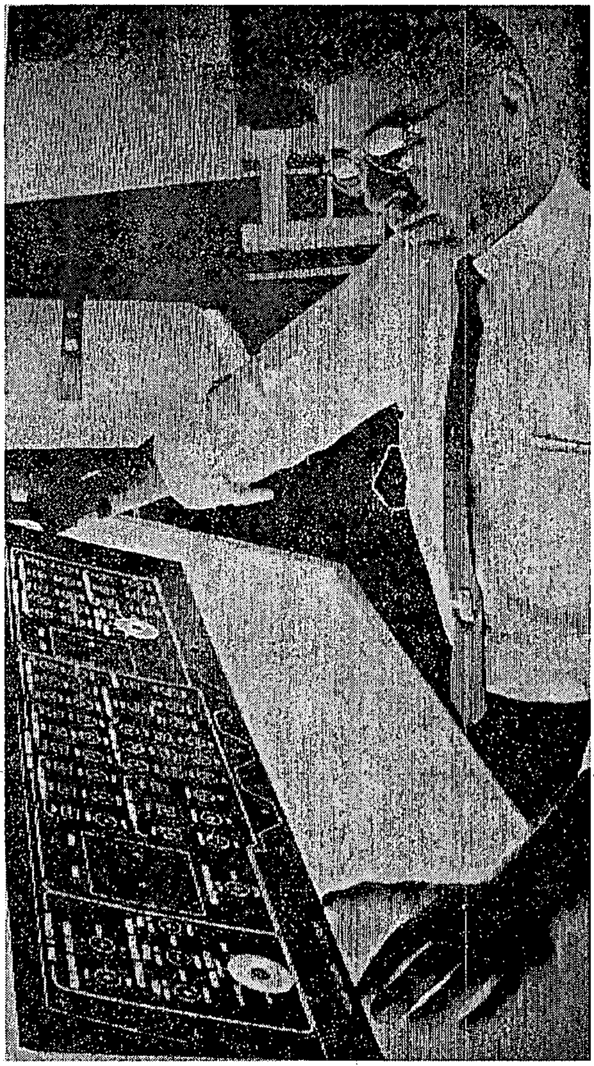
Another product line that U.S. Radium entered was the manufacture of industrial smoke detectors. Although the concept was invested by Albert Einstein, the earliest commercially available industrial smoke detectors were only begun to be manufactured in the early 1960s. The earliest versions used Radium 226, and U. S. Radium was one of the companies involved in installing the radium into the detector, under the product name Ionotron.[xlv]. By the time that residential units were commercially available, in the 1970s, new technologies were in place and U.S. Radium was no longer involved in this industry.

Front of an early 1960s Radium-style Smoke Detector

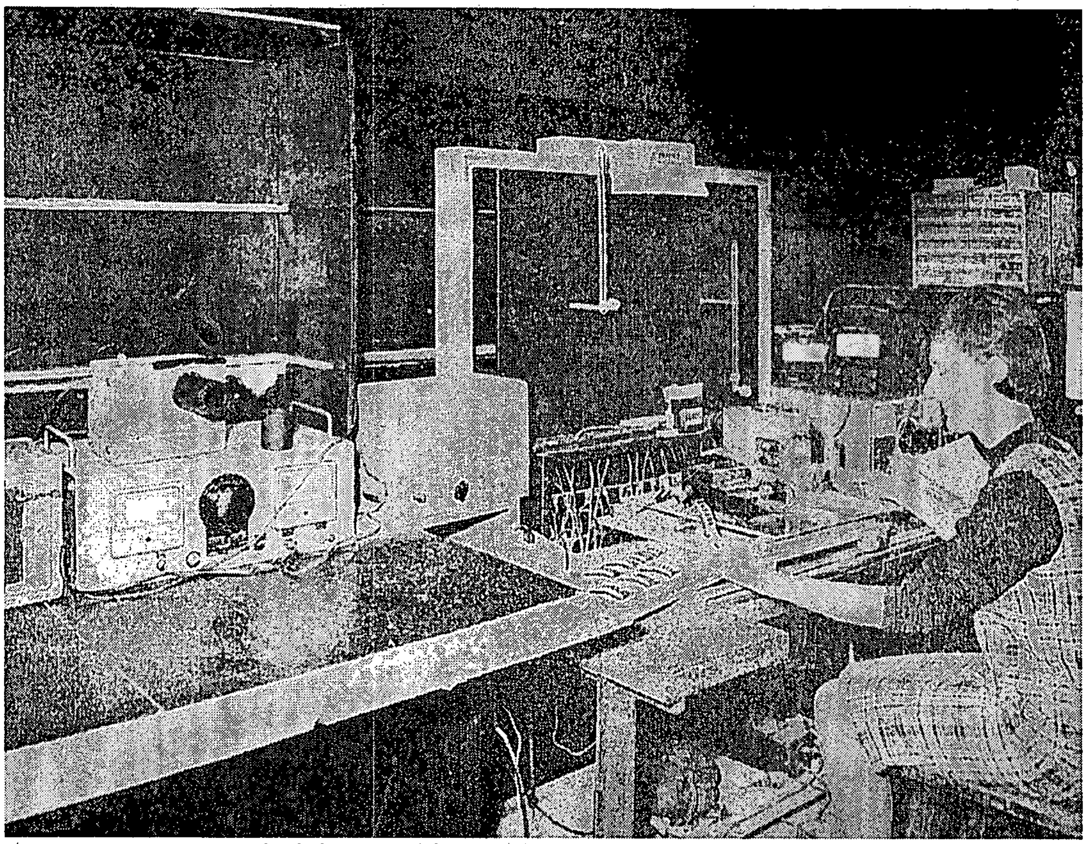


Red arrow illustrating location of Radium insert

Plant manager William Umstead reported that 1964 had the highest employment to date. They were manufacturing an automotive line of clock dials, and other electrical appliance dials and panels. In 1965, they received a contract from Grumman Aircraft to manufacture the cockpit lighting for the Lunar Excursion Module (L.E.M.).[xlvi] The Lunar Module was built by Grumman Aircraft Engineering and was chiefly designed by the American aerospace engineer, Tom Kelly.[4] Grumman had begun lunar orbit rendezvous studies in late 1950s and again in 1962. In July 1962, eleven firms were invited to submit proposals for the LEM. Nine did so in September, and Grumman was awarded the contract that same month. The contract cost was expected to be around $350 million. There were initially four major subcontractors—Bell Aerosystems (ascent engine), Hamilton Standard (environmental control systems), Marquardt (reaction control system) and Rocketdyne (descent engine). The LEM first successfully landed on the moon on July 20, 1969, with Neil Armstrong and Edwin "Buzz" Aldrin Jr.



U.S. Radium Engineer inspecting Tritium-lighted Instrument Panel for Lunar LEM



Technician working on instrument dials for NASA

Medical Appliances

U.S. Radium also became involved in new development in X-ray technology in the 1960s. These developed a new form of rare earth x-ray intensifying screen with three to ten times faster resolution. They also developed a more effective dental x-ray film. Unfortunately, in the 1970s, the Eastman Kodak Corporation decided to expand into medical films, and was able to force U.S. Radium out of that business. URSC eventually sold the entire product line to the GAF Corporation, one of Kodak's chief competitors/

Television Phosphors

The company's movement into producing phosphors for color television tube production was significant. Standard television sets have a layer of phosphors on the inside of the screen. As the phosphors are bombarded by electrons, the screens are lit up and the images on the television become visible. In 1966, it was reported that in 1962 this product line was responsible for only 25% of the companies, but by 1966 is amounted to more than 50% of their profits.[xlvii] Most of this work was produced at plant they constructed in Whippany, New Jersey.

Although it was becoming a major part of their company through the 1960s, the economic turmoil of the 1970s caused a dramatic reduction in color television sales, and coupled with the development of transistors and micro-technology, sales of these phosphors waned and eventually caused the company to cease the production of these phosphors.

Regulated out of Business

U.S. Radium became an issue of a number of environmental lawsuits in the 1980's. All of their early plant sites became suspect, and when tested, were found to be highly contaminated with radium and other radioactive wastes. At the plant at 60-06 27th Avenue, Queens, New York, remediation workers found 2,000 glass vials of radium.[xlviii] In 1983, the EPA found that the former US Radium site in Orange, New Jersey, had been used as a fill site, and numerous houses in the area had been built on top of land containing radioactive fill.[xlix] The affected residents sued U.S. Radium and recouped at least part of their costs for the cleanup.

The plant at 235 East 44th Street, Manhattan, was used as office space by U.S. Radium between 1939 and 1944. Because of the other plants, the EPA researched all of their facilities. At the 44th Street site, only trace amounts of radium were detected in the drains and in exposed paint samples.[l]

As of the 1980's, they were still doing a good business in the tritium lighting and sign business. Their main customer base was in the airline industry. An invoice from that year included their major clients as Air France, Air India, American Airlines, Boeing, Delta Airlines, Japan Airlines, Lufthansa Airlines, Sikorsky Air, TWA, and United Airlines.

The final demise of the Bloomsburg facility occurred in 1994, when the manufacture of items using tritium was banned in the United States. The company was forced to move its entire tritium processing operation to Canada. Coupled with the deterioration of the plant, and worsening concerns about the health issues at the plant, it was finally decided to cease all production at the Bloomsburg plant. The Safety Light Corporation was a small firm by the time it ended its operations in Bloomsburg, having only about 28 employees.[li]

Worker Health and Safety

The people employed in the management and the ore processing at the USRC plant were intuitively aware of the health risks associated with the ore. In 1917, Florence Wall, an employee of USRC and a graduate of St. Elizabeth's college, calculated the radioactivity of the ore and always wore a full length lead lined apron when working with it. A Gordon Cameron, who was tasked to move the tailings from the plant to a dump site on Alden Street, used rubber aprons, shoes and buckets to try to insulate himself from the radiation. Even the inventor of Undark Paint, and director of the company, Dr. Sabin von Sochocky, was said to have "hacked" off a fingertip when a piece of radioactive ore became lodged under a fingernail.[lii] In 1928, Dr. von Schlocky died of radium poisoning as well.[liii]

As it decays, it also gives off Radon gas, which can produce other detrimental health effects. The direct contamination can result in bone cancer and leukemia, while the exposure to radon gas can cause lung cancer. The toxic affects of the radon gas were not recognized until the mid 1930s, and it was not until the 1960s that a definitive association between radon gas and radioactive mine tailings was accepted. Even so, it was not until 1978 that radioactive mining tailings began to be regulated by the Environmental Protection Agency.[liv]

As for the watch painters, in the aftermath of the "Radium Girls" trial, U.S Radium implemented strict health and safety operations at their new plant in Bloomsburg. The new facility incorporated the use of ventilated hoods in all of their processes, so harmful gases would be taken away for m the workers and discharged into the air. Areas were established for decontamination. The workers were supplied with coveralls, lab coats, shoe covers and gloves, as required by the different tasks, so they would not have to take any contaminated clothing home with them. Laundry facilities were established on site to wash the laboratory wear.

Staff were personally are examined medically three times per year at the Bloomsburg Hospital. Blood counts, complete medical examinations, and finger inspections are part of the procedure."Because of its negative past history, U.S. Radium did all it could to encourage the safe handling of the radioactive materials. The employees were not to ingest the paint in any way. There was a fluoroscope room that each employee had to pass through to ensure they were not contaminated, and they were encouraged to wash their hands and face frequently.

Concerns continued however, and in the early 1980's the Argonne National Laboratory in Chicago conducted a nationwide health screening of people involved in the dial manufacturing process. In all, about 1,500 people involved in the industry were tested; including about 20 people from the Bloomsburg plant, and the study reported in 1984 that there was no measurable health effects in the people tested during this study.[lv]-This study helped confirm that the application of proper health and safety procedures has a measurable benefit to the workers in high-risk industries.

By at least 1963, the workers were unionized under the Oil, Chemical and Atomic Workers Union (AFL-CIO). Although arbitration with the union was largely focused on issues around pay and work hours, they also served as a double-check on the employees safely issues.

U.S. Radium was also cited and fined repeatedly from the 1960s to the 1980s for frequent released of tritium and other waste gases and affluent in to the environment. In 1966 alone, there were fifty-one instances of releases of tritium into the effluent above the maximum permissible concentration.[lvi]

There was also the misuse of waste materials. Several local residents reported that they were permitted to take waste products home with them to use as an effective "weed killer."[lvii]

By far, the biggest release of chemicals into the environment occurred in June 1972, when the Susquehanna overflowed its banks due to Hurricane Agnes. During that event, the waste product being stored in the old Susquehanna Canal was flushed into the river, underground storage tanks and metal drums were broken open and spilled. One 2,500 gallon tank was full of product, and totally emptied into the river.[lviii] The release was not able to be calculated, but it was considered a major impact to the environment.

In 1949 the US Congress passed a bill making all occupational diseases compensable, and extended the time during which workers could discover illnesses and make a claim. The Radium Girls and other cases of occupational abuse led ultimately to the development of the Occupational Safety and Health Administration (OSHA) in 1970./

Facilities

Buildings Key at Bloomsburg Facility (ATSDR 2009)

The facility consists of ten structures, which are grouped into three types of building styles. Style #1: The Main building , which is the oldest, largest, and most radioactively contaminated building on the Site appears to be constructed of wooden internal members (possibly with some metal internal member as well), and the exterior materials are stucco and brick. The roof of the Main building is a combination of metal and asphaltic roofing materials. The majority of the building identified as the Multi-Metals Waste Treatment building is of similar construction, and may have comprised a former power plant on the property. The Carpenter Shop exhibits construction characteristics similar to the Main building and Multi-Metals Waste Treatment building.

1. Etching Building where acids were used in the assembly and manufacture of radium and tritium instruments and dials. Some areas of the building were used for support services, such as silver plating, chemical storage, maintenance activities, machining tools and dies, and office space;
2. An old house built in the 19th century. The house was struck by lightning, burned and collapsed upon itself. In 1978, a survey by the USNRC indicated widespread radiologic contamination;
3. The Radium Vault was thought to be used for working with lead as well as various radium

compounds. The regulatory agencies believe all radiologicals have been removed from the vault but its condition is too dangerous for personnel to enter as it is structurally unsound;

4. Machine Shop and Tritium Building were used in the manufacture of tritium containing products. In 1969, the tritium operations were moved from the machine shop to the tritium building. After the move, the machine shop did not perform any work with radioactive materials;
5. The personnel office or nurses' station, located in front of the main building was used for administrative purposes but later was used to store radium materials. It is thought that a cellar below the building may be contaminated;
6. The main building housed the administrative activities of the company. However, the upper floors were used to hand-paint radioactive materials onto various products. That floor as well as ductwork in the facility is contaminated;
7. Waste processing and holding structures including the carpenter shop, Multimetals waste processing building, solid waste buildings, and an above ground metal silo to the rear of the facility were used to store various types of wastes, contaminated equipment, and radioactive materials such as Cs 137 and Sr 90; and
8. The Lacquer storage building where solvents had been stored.

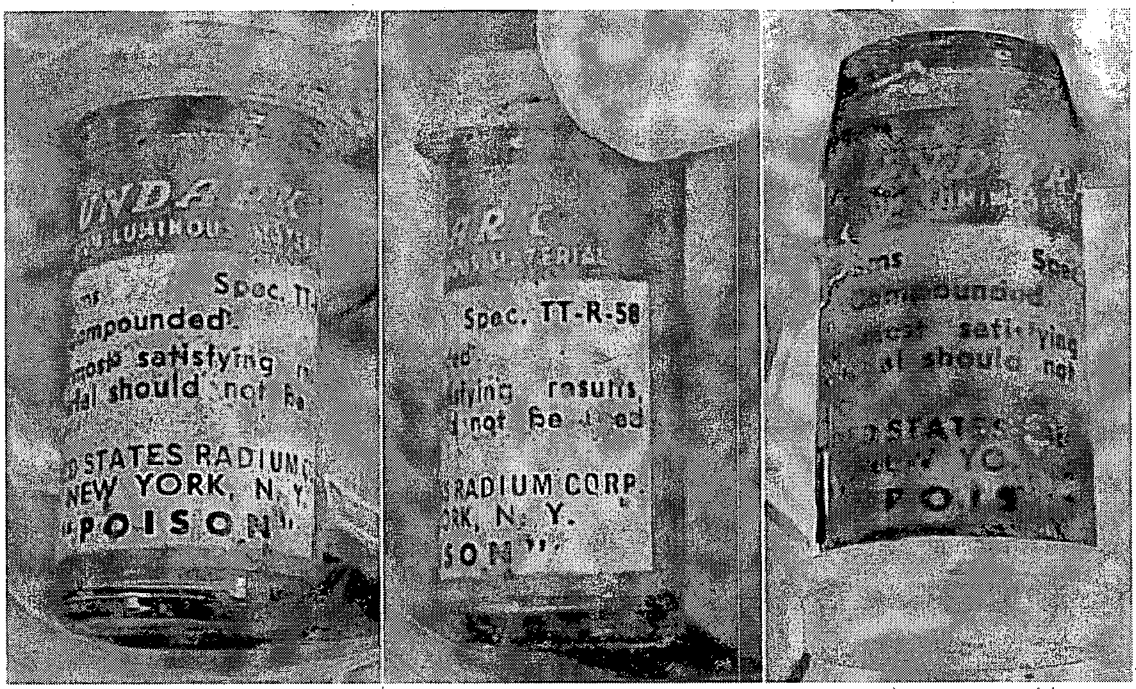
Waste Disposal

Between 1948 and 1951, they constructed two underground silos for the disposal of radioactive waste (PaDEP 2011). A 1953 inspection of the facility reported that liquid wastes, some of which were radioactive, were being discharged by the company into a dry well. Another inspection, in 1959, reported that the wastes were then going into open lagoons for processing and eventually, being released directly into the adjacent North Branch of the Pennsylvania Canal and subsequently draining into the Susquehanna River [lix]

During the production of the various devices made by SLC during the 1950s, radioactive solid wastes consisting of contaminated glassware and laboratory wastes including Ra 226, Sr 90, Cs 137, and tritium were placed in two underground silos, on the southern portion of the site, which were 12 feet deep by 10 feet wide. A memo from 1953 described the waste handling as routine: "The company disposes of contaminated glassware and some solid wastes which are encountered in processing Commission-distributed radioisotopes by sealing them in a metal containers which is then thrown into the steel-lined disposal pit. Instrument dials containing natural radioactivity, such as Radium, are thrown into this pit without being placed in a container."[lx] The SLC staff believed these silos either had no solid base or the base was either metal or concrete (2). When the silos were closed in 1960, the wastes were shipped off-site to licensed radioactive waste burial facilities. No further remediation was undertaken at that time.[lxi]

It was mentioned in a memorandum from 1953 that U.S. Radium was also disposing of some of its wastes by hiring a contractor who hauled the material into the open ocean and dumped it. The disposal company was Radiation Services Company, in New York, who put the radioactive waste into 5-gallon paint buckets and dropped them into the ocean.[lxii]

In another memorandum, in 1954, it was discussed that U.S. Radium was considering building a two-tank holding system for their radioactive wastes, one tank which would be designed to dilute the waste product and their discharge it directly into the middle of the Susquehanna River. The Atomic Energy Commission felt that "it was our general impression that radioisotopes being used at U.S. Radium Company at Bloomsburg are being handled under exceptionally good conditions of radiological safety." [lxiii]



Luminous Paint recovered from waste at Bloomsburg Facility (ATSAD, 2009)

Along the Susquehanna River, a canal traversed the SLC property. The canal, in its entirety, ran from Sunbury to Scranton, a distance of about 90 miles. Available information states that the portion of the canal along the SLC property may have consisted of at least 7 lagoons. SLC used the former canal and some of the associated lagoons as liquid waste disposal areas. Liquid wastes produced on the site were routed to a nearby abandoned canal associated with the Susquehanna River where they were filled with river water, allowing the wastes in them to be diluted prior to discharging into the river. Other wastes were transferred to a holding tank and evaporator system (4). The concentrated liquid wastes were allowed to evaporate, and the dry residuals were transferred to a waste company.

In 1960, the neighbors began to complain about the smell from these canal storage areas, ad the AEC ordered U.S Radium to investigate the problem and come up with an acceptable solution.[lxiv] During the 1960s, three of the lagoons on the eastern side of the facility were remediated and backfilled. Currently, two lagoons are considered to be active on the site. The East Lagoon received both sewage and radioactive wastes until 1954. In 1972 during the Susquehanna flooding, the wastes remaining in the lagoon were probably distributed on the surrounding soils. The West Lagoon is believed to have received wastes associated with metal plating activities and in 1972 these wastes most likely were dispersed as well by the flooding. Two dump areas also have been identified on the site. The East Plant Dump is between the east and west lagoons and received radiological contaminated ductwork and scrap materials. The West Plant Dump adjacent to the west fenceline also was used for solid waste disposal. The materials known to have been dumped in this location include Ra 226 dials and Sr 90 deck markers. SLC states that 78 drums of contaminated soils were shipped from this area in either the 1960s or 1970s.[lxv]

In addition, the Environmental Protection Agency was becoming increasingly concerned about contamination at the site, and issued a permit in 1969 for decommissioning the site. At the same time, the Atomic Energy Commission began to cite the company for lax handling standards of radioactive materials, and for uncontrolled and poorly monitored releases of tritium gas into the atmosphere.[lxvi] The company continued to operate, and transferred the nuclear division of their company to a new corporation, the Safety Light Corporation, in 1983. The site's major activity was the manufacture of exit signs and aircraft signs containing tritium, which included the filling of the tubes used in the signs. Tube filling operations ceased around 1994, which drastically reduced the environmental releases of tritium from the site. Manufacture of tritium foils ceased in mid-2007, and the receipt of returned signs for recycling ceased on October 31, 2007. All activities ceased on December 31, 2007.[lxvii]

The environmental issues at the Bloomburg site were further aggravated in 1972, when Hurricane Agnes occurred. The Susquehanna River flooded part of the site, including the containment lagoons. Additionally, a liquid radioactive waste holding tank and evaporator were destroyed during the flood.[lxviii]

The complex has been deteriorating due to neglect. The roofs of several buildings have collapsed. In 1998, the upper story of a contaminated frame building burned, and in 2003 a hurricane toppled a tree into it causing significant damage (PaDEP 2011). The only Safety Light employee on site is now a guard two protects the property from vandalism.

Other Similar Operations

In addition to the US Radium Corporation, there were other similar radium dial painting operations around the country. The largest and most notorious after the Orange plant was the factory of the Radium Dial Company, of Ottawa, Illinois. It was a direct subcontractor to the Westclox Watch Company, and supplied all of their painted watch dials. The period of time that were using Undark for painting followed a similar practice and results as the US Radium factory, with a number of women contracting cancer and dying from the unsafe work practices. It declared bankruptcy in 1936, but a new company arose in 1937 called Luminous Processes which had the same president, Joseph Kelley Sr. Although radium dials began to be out of fashion, Luminous Products received a lucrative military contract and continued to paint the dials on military vehicles. They were eventually shut down in 1976 by the EPA.[lxix]

Other smaller watch and dial painting operations were scattered throughout the country, but none ever some large or prominent as U.S. Radium and the Radium Dial Company. The Seth Thomas Watch Company had a painting operation in Thomaston and Waterbury, Connecticut, after U.S. Radium began exporting its watch painting operations directly to the customers' factories.[lxx] The Elgin Watch Company had one in Elgin, Illinois, and there were small facilities in Boston, Pittsburgh and elsewhere.[lxxi]

A more recent example of radium-affected properties in Pennsylvania involves the Karnish Instrument site, located at the Piper Airport, Lock Haven, Pennsylvania. Karnish Instruments was a manufacturer and repair facility for aircraft instruments. As a part of their operation, they removed the radium paint from the aircraft instrument dials, and repainted them with modern, non-toxic materials. However, they apparently disposed of the contaminated paint on site, and resulted in a hazardous material cleanup operation at the plant by the Commonwealth of Pennsylvania (Nuclear Regulatory Commission 2011b).

Significance

The original US Radium Corporation plant at Orange, NJ was determined eligible for its association with the radium paint industry, during its period of significance from 1917-1926. The historic significance of this facility is derived from its association with the development of modern worker health and safety laws and regulations in the United States. After the Radium Girls trial, the Consumers' League of New Jersey fought to make industrial radium poisoning compensable under the state workers' compensation act, and in 1993 forced the development of safe handling regulations for the dial painting industry[lxxii]. Ultimately, this case and others led to an industrial health movement in the 1960's and led to the development of the Occupational Safety and Health Administration in 1970. Although the facility was considered historically significant, but since it was heavily contaminated, it was subjected to extensive HAER document prior to demolition and site cleanup by the EPA.

The Bloomsburg facility, although a part of the history of the U.S. Radium Corporation, plays a subordinate role to the industrial hygiene history of the Orange facility. It was considered significant by the Pennsylvania Historic Preservation Office for its local significance to the Bloomsburg area, as it changed its processing technologies away from the harmful radium and into better applications for military and medical devices. It was an innovator in a number of mechanical devices, including tritium lighting, night vision gun scopes, television screens, luminous dials for military and aviation applications, luminous markers, and industrial smoke detectors. Although new technologies have been developed which have made most of their radioactive applications obsolete, they were critical in the development of specialized military and aviation equipment, including its application during the Moon landing.

It was also significant as a major employer in the Bloomsburg area. Bloomsburg was under going significant economic distress in the 1940s with the abandonment of old industries. When U.S. Radium purchased their plant in Bloomsburg, they found a ready workforce. From the 1950's until the early 1970's, U.S. Radium employed about 500 person, providing a secure employment for a large percentage of the community. -

References

ATSDR
2009 Public Health Assessment, Safety Light Corporation, Bloomsburg, Pennsylvania. Agency for Toxic Substances and Disease Registry, Atlanta, Ga.

Berkeley (CA) Daily Gazette
1922 "Radium Exhibits will be Made by University Here." January 12, 1922

Clark, Claudia
1997 "Radium girls", University of North Carolina Press, Chapel Hill.

Pennsylvania Department of Environ mental Protection (PaDEP)
2011 Safety Light Corporation Superfund Site, Bloomsburg, PA. http://www.dep.state.pa.us/brp/Decom_and_Env_Sur/PA_Decommissioning_Site_Summaries.htm, accessed June 17, 2011/

Evening Independent (St. Petersburg, FL)
1925 "Radium Poison Fatal to Woman" June 19, 1925

Gettysburg (PA) Times
1959 "Radiation Poisoning Fatal to 43rd Person" April 27, 1959.

Glassmire, Charles
2010 The Radium Girls. Tales from the Nuclear Age, at http://talesfromthenuclearage.wordpress.com/2010/09/13/the-radium-girls-2/ (accessed June 16, 2011)

Manta
2011 Safety Light Corporation. http://www.manta.com/c/mm2mt8j/safety-light-corp, accessed June 17, 2011

Museum of Learning
n.d. United States Radium Coproration, at http://www.museumstuff.com/learn/topics/United_States_Radium_Corporation::sub::History (accessed June 16, 2011)

National Park Service..
n.d. U.S. Radium Corporation, Historic American Engineering Record, HAER No NJ-121. Historic American Engineering Record.

New York Times
1921 "Radium Plants Combines." September 2, 1921.

Nuclear Regulatory Commission

2011a Safety Light Corporation (Commonwealth of Pennsylvania). http://www.nrc.gov/info-finder/decommissioning/complex/safety-light-corporation-slc-.html, accessed June 17, 2011.

2011b Karnish Industries (Commonwealth of Pennsylvania) http://www.nrc.gov/info-finder/decommissioning/complex/karnish-instruments.html, accessed June 16, 2011.

Palm Beach Press
1928 "Agreeable Outcome in Radium Poison Trials for Women," June 5, 1928

Radium Girls
n.d. Radium Girls, www.radiumgirls.com. Accessed June 16, 2011.

St. Joseph News Press
1933 "Radium Poison Kills: Woman Officially Doomed in Court Action Succumbs." October 27. 1933"

St. Petersburg (FL) Times
1928 """Five Condemned to Death." May 20, 1928.

Steffen, D.
2009 "How Regulation came to Be: Radium Girls".
http://www.dailykos.com/story/2009/3/1/703389/-How-Regulation-came-to-be:-Radium-GirlsPart-I, accessed June 17, 2011

Stannard, J.N. Radioactivity and Health: A History. DOE/RL/01830-T59. Battelle Memorial Institute. 1988.

Supreme Court of New Jersey
1991 T & E Industries vs. Safety Light Corporation, USR Industries, Inc.; USR Lighting, Inc.; USR Metals, Inc.; USR Chemicals Inc.; and US Natural Resources, Inc. Argued March 12, 1990, Decided March 27, 1991.
Wikipedia
n.d. Tritium Illumination. http://en.wikipedia.org/wiki/Self-powered_lighting, accessed June 17, 2011.

Endnotes

[i] Madam Curie and the Science of Radioactivity, at www.aip.org/history/curie/stud1.htm, accessed 29 August 2011.

[ii] "Rochester (NY) Democrat, "Bell First to Recommend Radium Remedy", 25 February 1914.

[iii] "Radium and Radioactivity", Mme. Sklodowska Curie, *Century Magazine* (January 1904), pp. 461-466

[iv] Glassmire 2010
[v] New York Times, "Radium Plants Combine", 2 September 1921
[vi] New Jersey Supreme Court, 1994
[vii] National Park Service, no date, 18
[viii] National Park Service, no date, 68
[ix] Museum of Learning, n.d.
[x] U.S. Radium Corporation, Annual Report, 1975 and subsequent years
[xi] United States Radium Corporation,
Stockholders Report, dated 11 July 1980.
[xii] U.S. Radium Corporation, Annual Report, 1979
[xiii] National Park Service, no date, 14.
[xiv] National Park Service, no date, 16
[xv] New Jersey Supreme Court, 1991
[xvi] Steffen 2009
[xvii] National Park Service, no date, 28
[xviii] Berkeley Daily Gazette, 1922
[xix] National Park Service, no date, 23
[xx] Radium Girls, n.d.
[xxi] Radium Girls, n.d.
[xxii] Museum of Learning, n.d.
[xxiii] Evening Independent, 1925
[xxiv] Glassmire, 2010
[xxv] Palm Beach (FL) Press, June 5, 1928
[xxvi] Radium Girls, n.d.
[xxvii] St Joseph News Press, October 27, 1933
[xxviii] Gettysburg Times 1959
[xxix] New Jersey Supreme Court, 1991
[xxx] Museum of Learning, n.d.
[xxxi] New Jersey Supreme Court, 1991
[xxxii] New Jersey Supreme Court, 1991
[xxxiii] Bloomsburg Morning Press, "Company Head in Visit Here", 21 May 1948.
[xxxiv] Memorandum, George G. Manov, Chief, AFSB, dated June 26, 1951
[xxxv] Memorandum, George G. Manov, Chief, AFSB, dated June 26, 1951
[xxxvi] Bloomsburg *Press Enterprise*, "Firm's Health OK Questioned", 1 August 2004, on file at the Columbia County Historical Society, Bloomsburg, PA
[xxxvii] Memorandum of J. W. Hitch, AEC, dated December 18, 1957
[xxxviii] Memorandum of Cecil R. Buchanan and C. m. Ferrell, dated April 8, 1957
[xxxix] Letter dated May 18, 1951, C. C. Carroll, Chief Chemist, Safety Light Corporation, to Dr. Allen Lough, U.S. Atomic Energy Commission, Oak Ridge.
[xl] Memorandum of P. M. Frazier, Advisory Field Services Bureau, Atomic Energy Commission, April 29, 1953

[xli] Memorandum of Robert F. Barker, A.E.C., dated November 7, 1955
[xlii] Memorandum of Cecil S.. Buchanan and C. M. Ferrill, AEC, dated April 8, 1957.
[xliii] Memorandum of J. W. Hitch, AEC, dated December 18, 1957
[xliv] United States Radium Corporation Annual Report, 1959
[xlv] http://www.orau.org/ptp/collection/consumer%20products/radiumsmokedetector.htm
[xlvi] Bloomsburg *Morning Press*, "U.S. Radium Is Optimistic", 23 January 1965, on file at the Columbia County Historical Society, Bloomsburg, PA
[xlvii] Report, United States Radium Corporation to American Stock Exchange, dated November 2, 1966
[xlviii] New York Times, "Abandoned Queens Factory Studied for Radiation." 18 September 1987
[xlix] New York Times, "Living with a Radium Nightmare," 29 September 1996
[l] New York Times, "High Radiation in Plant on East 44th St.", 5 May 1988
[li] Manta 2011
[lii] New Jersey Supreme Court, 1991
[liii] New York Times, "Radium Takes its Inventor's Life:,15 November 1928
[liv] New Jersey Supreme Court, 1991
[lv] Bloomsburg press Enterprise, "Firm's Health OK Questioned", August 1, 2004
[lvi] Bloomsburg Press Enterprise, "History of Safety Violations", August 8, 2005
[lvii] Bloomsburg Press Enterprise, "Family Suspects Chemicals in Illness", 2 October 2005
[lviii] Bloomsburg Press Enterprise, "History of Safety Violations", August 8, 2005
[lix] Nuclear Regulatory Commission 2001a; PaDEP 2011
[lx] Memorandum of P. M. Frasier, AEC, dated 28 September 1953
[lxi] ATSDR 2009
[lxii] Memorandum of P. M. Frasier, AEC, dated 28 September 1953
[lxiii] Memorandum of Oscar M. Russell and Lester R. Rogers, AEC, dated April 14, 1954
[lxiv] J. G. MacHutchin, U.S. Radium, Progress Report on Disposal of Canal Wastes,7 July 1960
[lxv] ATSDR 2009
[lxvi] J. R. Roeder, AEC, Memorandum dated 16 June 1969
[lxvii] NRC, 2011a
[lxviii] PaDEP 2011
[lxix] Steffen 2009
[lxx] Clark, 1997, p. 108.
[lxxi] Steffen 2009
[lxxii] Clark 1997, p. 205